PATENT ABSTRACTS OF JAPAN

(11)Publication number : **07-188847**

(43)Date of publication of application : **25.07.1995**

(51)Int.Cl. **C22C 38/00**

C22C 38/04

(21)Application number : **05-337876**

(22)Date of filing : **28.12.1993**

(71)Applicant : **KAWASAKI STEEL CORP**

(72)Inventor : **IWAMOTO TAKASHI**
HOSHINO TOSHIYUKI
MATSUZAKI AKIHIRO
AMANO KENICHI
KAWASAKI ATSUMI
FUJITA TOSHIO

(54) MACHINE-STRUCTURAL CARBON STEEL EXCELLENT IN MACHINIABILITY

(57)Abstract:

PURPOSE: To easily and industrially obtain a steel material superior in machinability to conventional Pb free-cutting steels.

CONSTITUTION: This steel has a composition consisting of, by mass, 0.1-1.5% C, 0.5-2.0% Si, 0.1-2.0% Mn, 0.0005-0.03% REM, 0.0015-0.0150% N, ≤0.0030% O, and the balance essentially Fe and further containing, if necessary, one or ≥2 kinds selected from the following: a group consisting of 0.05-1.0% Cr and 0.05-0.5% Mo; a group consisting of 0.1-3.0% Ni, 0.1-3.0% Cu, 0.05-0.5% V, 0.005-0.05% Nb, 0.01-0.5% Al, and 0.005-0.05% Ti; a group consisting of 0.03-0.30% Pb, 0.002-0.50% Te, 0.030-0.15% P, 0.0002-0.30% Ca, 0.01-0.30% Bi, 0.003-0.10% Se, and 0.030-0.25% S; and 0.0003-0.0150% B. Further, this steel has a metallic structure composed essentially of ferrite and graphite.

LEGAL STATUS

[Date of request for examination] 27.12.2000

[Date of sending the examiner's decision of rejection] 28.01.2003

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to machine structural carbon steel excellent in machinability.

[0002]

[Description of the Prior Art] Cutting is the processing approach used for manufacture of almost all machine parts. Conventionally, as a free cutting steel, what added free-cutting elements, such as Pb, S, Bi, Ti, and calcium, to machine structural carbon steel or alloy steel is used abundantly. However, what is added as a free-cutting element has many things harmful to the body. Therefore, a large-scale exhaust air facility is not only needed, but in the production process of steel materials, there is a problem also from a viewpoint of recycle of steel materials. Then, development of the steel materials which have the machinability which was excellent, without using these free-cutting elements was desired.

[0003] The method of improving machinability is indicated by making C in steel exist in JP,49-67816,A, a 49-67817 official report, a 49-103817 official report, and a 50-1913 official report as a graphite, and using the notching lubrication effectiveness of this graphite for them as what responds to the above-mentioned request, without using Pb, Bi, etc. However, according to examination of this invention persons, in order hardening to be not only required of such steel as pretreatment, but [in order to graphitize C in steel,] for graphitization processing to take long duration remarkably, operation on a industrial scale is very difficult. Moreover, even if graphitization is completed, since the graphite particle size after processing is very large, it is hard to say that it has the machinability which was not necessarily excellent.

[0004] Then, this invention persons came to get the conclusion described below, as a result of examining wholeheartedly the machinability of the steel materials which graphitized the inside C of steel. The machinability of the steel materials which graphitized the inside C of steel receives effect in extent of graphitization, the particle size of a graphite, and the hardness after graphitization. That is, if extent of graphitization after graphitization processing is bad and a non-decomposed cementite remains so much, machinability will fall. Since a cementite is hard very much, this reason is because this wears a cutting tool. Moreover, graphite particle size also does effect and, as for graphite particle size, machinability of direction of a fine grain improves. The device of cutting of graphitic steel is because a detailed crack occurs in the interface of the graphite in steel materials, and a host phase and this crack connects with it in the field to which **-ed

material receives shearing stress from a tool. Therefore, machinability improves, so that many particle size of a graphite grain exists in the case of the one of the same graphites where spacing of a graphite grain is smaller, i.e., the amount, small finely [the particle size of a graphite grain]. Furthermore, although the hardness of steel also affects machinability as known well, according to examination of this invention persons, the magnitude of the effect these factors affect machinability has the largest rate of graphitization, and, subsequently to the order of the hardness of graphite size and **-ed material, becomes.

[0005]

[Problem(s) to be Solved by the Invention] This invention is based on the above-mentioned knowledge, and aims at proposing the machine structural carbon steel which has improved effectively, had the rate of graphitization, graphite particle size, and the hardness of steel materials, and realized much more improvement in machinability by adjustment of a component presentation.

[0006]

[Means for Solving the Problem] That is, the summary configuration of this invention is as follows.

1) C:0.1 - 1.5 mass% Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass% Mn:0.1 - 2.0 mass% Si:0.5 - 2.0 mass% including less than [O:0.0030mass%].

[0007] 2) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, O: Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite including less than [0.0030mass%] B:0.0003 - 0.0150mass%.

[0008] 3) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, less than [O:0.0030mass%] -- containing -- and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0009] 4) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0010] 5) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, Cu: 0.1 - 3.0 mass%, and V:0.05 - 0.5 mass %, Nb:0.005 - 0.05mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an

unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0011] 6) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included. And nickel:0.1 - 3.0 mass% Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% Nb:0.005 -0.05mass%aluminum:0.01 - 0.5 mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0012] 7) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, less than [O:0.0030mass%] -- containing -- and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is nickel:0.1 - 3.0 mass%. Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% Nb:0.005 - 0.05mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0013] 8) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005-0.0300mass%N:0.0015 - 0.0150mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is nickel:0.1 - 3.0 mass%. Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% Nb:0.005 - 0.05mass%aluminum:0.01 - 0.5 mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0014] 9) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] is included N:0.0015 - 0.0150mass%. And Pb:0.03 - 0.30mass% Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0015] 10) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included N:0.0015 - 0.0150mass%. And Pb:0.03 - 0.30mass% Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.
[0016] 11) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005

- 0.03mass%, Less than [O:0.0030mass%] is included N:0.0015 - 0.0150mass%. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 - 0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0017] 12) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included N:0.0015 - 0.0150mass%. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0018] 13) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] is included N:0.0015 - 0.0150mass%. And nickel:0.1 - 3.0 mass% Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% -- and -- One sort chosen from from while of Nb:0.005 - 0.05mass%, or two sorts or more are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0019] 14) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included N:0.0015 - 0.0150mass%. And nickel:0.1 - 3.0 mass% Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% Nb:0.005 -0.05mass%aluminum:0.01 - 0.5 mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0020] 15) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] is included N:0.0015 - 0.0150mass%. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is nickel:0.1 - 3.0 mass%. Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% -- and -- One sort chosen from from while of Nb:0.005 - 0.05mass%, or two sorts or more are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 -

0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0021] 16) C:0.1 - 1.5 mass% Si:0.5 - 2.0 mass%, Mn: 0.1 - 2.0 mass% and REM:0.0005 - 0.03mass%, Less than [O:0.0030mass%] B:0.0003 - 0.0150mass% is included N:0.0015 - 0.0150mass%. and Cr:0.05 - 1.0 mass% -- and -- One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. Furthermore, it is nickel:0.1 - 3.0 mass%. Cu:0.1 - 3.0 mass%, V:0.05 - 0.5 mass% Nb:0.005 - 0.05mass%aluminum:0.01 - 0.5 mass% -- and -- One sort chosen from from while of Ti:0.005 - 0.05mass%, or two sorts or more are contained. Furthermore, it is Pb:0.03 - 0.30mass%. Te:0.002 -0.50mass%P:0.030 - 0.15mass%, calcium: 0.0002-0.30mass%Bi:0.01 - 0.30mass%, One sort chosen from from while of Se:0.003 - 0.10mass%, and S:0.030 - 0.25mass%, or two sorts or more are contained. Machine structural carbon steel excellent in the machinability characterized by for the remainder consisting of a presentation of Fe and an unescapable impurity, and moreover a metal texture mainly consisting of a ferrite and a graphite.

[0022]

[Function] Hereafter, in this invention, the reason which limited the component presentation of steel to the above-mentioned range is explained.

C: Although it is not only important when securing the reinforcement as a machine part, but is a component indispensable when forming a graphite phase, a content 0.1 -1.5 mass%C It is deficient in the improvement effect of machinability less than [0.1mass%], and one side. Since the deformation resistance at the time of hot rolling increased and the fall of hot rolling nature was caused when contained exceeding 1.5mass%, it limited to the range of 0.1 - 1.5 mass%.

[0023] Si: Although it not only promotes graphitization, but adds positively since it is an element useful also as a deoxidizer, it is deficient in a graphitization facilitatory effect less than [0.5mass%], and 0.5 -2.0 mass%Si is one side. When 2.0mass% was exceeded, the decarbonization at the time of hot rolling was remarkable, and since the mechanical property after hardening / annealing deteriorated, it limited to the range of 0.5 - 2.0 mass%.

[0024] Mn: Although it is an element useful when securing hardenability, it is deficient in the addition effectiveness less than [0.1mass%], and 0.1 -2.0 mass%Mn is one side. Since graphitization was remarkably checked when 2.0mass% was exceeded, it limited to the range of 0.1 - 2.0 mass%.

[0025] REM: Combine with S and 0.0005-0.0300mass%REM, i.e., rare earth elements, forms a sulfide. For example, La and Ce combine with S, and form S (La, Ce), and this (La, Ce) S acts as a nucleus of crystallization of a graphite. For this reason, detailed-ization of a graphite grain is also attained at the same time the time amount which graphitization takes is shortened. Therefore, it is at this invention. Although REM was added positively, when a content was not filled to 0.0005mass(es)%, even if it was deficient in the addition effectiveness and added exceeding 0.0300mass(es)% on the other hand, since the effectiveness reached saturation, it was limited to the range of 0.0005 -

0.0300mass%.
[0026] N: 0.0015-0.0150mass%N not only contributes to formation of the nitride and carbon nitride used as the nucleus of crystallization of a graphite, but Dissolution N contributes it effective also in an improvement of the machinability by dynamic strain aging. However, since hot-working nature would fall and it would become easy to generate a crack and a crack in steel materials if the absolute magnitude of the sludge with which a content serves as a nucleus of crystallization of a graphite less than [0.0015mass%] ran short and 0.0150mass(es)% was exceeded on the other hand, it limited to the range of 0.0015 - 0.0150mass%.
[0027] O: Form oxide system nonmetallic inclusion and the fatigue strength of a machine part is reduced, and also since the workability between the colds and between heat is degraded, decreasing as much as possible is desirable, but less than [0.0030mass%] O is permitted if it is to 0.0030mass%.
[0028] As mentioned above, although the fundamental component was explained, in this invention, the following elements can also be added further.
B: 0.0003-0.0150mass%B combines with N, forms BN, and this serves as a nucleus of crystallization of a graphite and it contributes effective in promotion of graphitization. However, since the cementite was stable and graphitization was conversely checked when the content was deficient in the ****** less than [0.0003mass%] and exceeded 0.0150mass(es)% on the other hand, it limited to the range of 0.0003 - 0.0150mass%.
[0029] Cr:0.05 - 1.0 mass% and Mo:0.05 - 0.5 mass% -- they are equal as an improvement element of hardenability, and Cr and Mo utilize and are useful when securing reinforcement required as a machine part by hardening / tempering processing. However, when these elements invade into a cementite, they also have the operation which a cementite is stabilized and delays graphitization. Therefore, while effectiveness was on the hardening disposition on the occasion of addition of these elements, it needed to add in the range which does not check graphitization and limited to the range of Mo:0.05 - 0.5 mass% Cr:0.05 - 1.0 mass% from this viewpoint, respectively.
[0030] nickel, Cu, V, Nb, and aluminum and Ti are elements equal as a graphitizer, respectively. nickel:0.1 - 3.0 mass% and Cu:0.1 - 3.0 mass% -- nickel and Cu are useful elements which speed up [graphitization] by making a cementite unstable, respectively, and by precipitation strengthening by both compound addition, since it contributes effective also in improvement in the reinforcement of a ferrite phase, when the reinforcement as a machine part needs to be secured by precipitation strengthening of hardening / tempering processing or a ferrite phase, it adds. However, a content all If it does not fill to 0.1mass%, it is deficient in the addition effectiveness, and it is one side. Since the deformability between heat will fall if 3.0mass% is exceeded, it is made to contain in 0.1 - 3.0 mass%.
[0031] V:0.05 - 0.5 mass%, Nb:0.005 -0.05mass%V and Nb form carbon nitride, respectively, and make the organization after hot rolling detailed by controlling gamma grain growth in the heating process of hot rolling, as a result contribute also to promotion of graphitization. Moreover, detailed carbon nitride is formed at the same time it raises hardenability, and it contributes also to improvement in reinforcement by the precipitation strengthening. Then, these elements are used when the reinforcement demanded as a machine part needs to be secured by hardening / tempering processing or precipitation strengthening. However, respectively, if a content is not filled to 0.05 and

0.005mass%, it is deficient in the addition effectiveness, and it is one side. Since the effectiveness reaches saturation, it is made to contain in Nb:0.005 - 0.05mass% V:0.05 - 0.5 mass%, even if it adds exceeding 0.5 and 0.05mass%.

[0032] aluminum:0.01 - 0.5 mass% and Ti:0.005 - 0.05mass% -- each of aluminum and Ti combines with N, forms a nitride, and when these act as a nucleus of graphite crystallization at the time of graphitization, it has the operation which promotes graphitization. Moreover, these elements are useful also as a deoxidizer. Then, a content is each although it adds if needed. Since the effectiveness reaches saturation and especially aluminum also has the disadvantage which causes the fall of the deformability between heat even if the effectiveness is small and adds exceeding 0.5 and 0.05mass% on the other hand if it does not fill to 0.01 and 0.005mass%, it is made to contain in Ti:0.005 - 0.05mass% aluminum:0.01 - 0.5 mass%.

[0033] Any one sort chosen from from among the following component elements or two sorts or more can be made to contain besides each above-mentioned component in this invention further again. Content of these elements makes the machinability of steel improve further conjointly with the improvement effectiveness of the machinability by the graphitization in [C] steel. In addition, graphitization is not checked even if it adds these machinability improvement element.

[0034] Pb: Since 0.03-0.30wt%Pb has the low melting point, it is an element which fuses by generation of heat of the steel materials at the time of cutting, and raises machinability remarkably according to the fluid lubrication effectiveness, but since graphitization is checked on the other hand and machinability is reduced conversely, in order to satisfy both properties, add it by 0.03 - 0.30wt% of within the limits.

[0035] Te:0.002 - 0.50wt% -- this Te forms MnTe, and when this acts as a chip breaker, it raises machinability. On the other hand, since it is also the element which checks graphitization, if it adds so much, machinability will deteriorate on the contrary. Then, while the contribution to machinability improvement was accepted, as a result of the inhibition to graphitization inquiring per [which is not accepted notably] within the limits, the proper amount is 0.002 - 0.50wt%.

[0036] P: Although 0.030 -0.15wt%P is an element which raises machinability by stiffening a ferrite phase, it is also the element which checks graphitization on the other hand. In order to raise machinability, it needs to be added beyond 0.030 wt% at least. However, since graphitization is checked and machinability is made to fall conversely when it adds exceeding 0.15wt%, 0.15wt% is added as an upper limit.

[0037] calcium:0.0002 - 0.30wt% -- this calcium forms the oxide of a calcium-aluminum system, and when this acts as a nucleus of graphitization and promotes graphitization, it improves machinability. Since oxide system nonmetal objects will increase in number and this will reduce the fatigue strength as a machine part if such an operation does not appear clearly in addition below 0.0002wt% but is added exceeding 0.30wt(s)% on the other hand, let the addition of this calcium be the range of 0.0002 - 0.30wt%.

[0038] Bi: Although 0.01-0.30wt%Bi is an element which fuses by generation of heat of the steel materials at the time of cutting, and raises machinability remarkably according to the fluid lubrication effectiveness since the melting point is low, since it checks graphitization on the other hand and reduces machinability conversely like Pb, in order to satisfy both properties, add it by 0.01 - 0.30wt% of within the limits.

[0039] Se:0.003 - 0.10wt% -- this Se combines with Mn, and by forming MnSe, when

this acts as a chip breaker, it improves machinability. Machinability is raised, when this MnSe serves as a nucleus of graphitization and promotes graphitization to coincidence. Since that effectiveness is saturated under with 0.003wt(s) % even if that effectiveness is small and adds exceeding 0.10wt(s)% on the other hand, this effectiveness is added by 0.003 - 0.10wt% of within the limits.

[0040] S: 0.030 -0.25wt%S forms MnS, by becoming the nucleus of graphitization, promotes graphitization and has the operation which raises machinability as the result while this acts as a chip breaker at the time of cutting and raises machinability. Since the addition was deficient in the effectiveness less than [0.030 wt%], it added more than 0.030wt(s) %, but since effectiveness was saturated even if it added exceeding 0.25wt(s)% by one side, the upper limit was made into 0.25wt(s)%.

[0041] By adjusting to the fundamental component presentation range mentioned above, a metal texture can get without the need for hardening as pretreatment the steel materials which mainly consist of a ferrite and a graphite. In addition, in metal texture, although the configuration of this invention needs to make it the organization which mainly consists of a graphite and a ferrite, it is desirable for about 50% of the amount of addition C to make it exist as a cementite, and to make a 0.05mass(es)% graphite phase contain at least during an organization from the free-machining point based on a lubrication action.

[0042] Next, the manufacture approach of this invention is explained. First, about manufacture of a material, after ingoting with a well-known converter, an electric furnace, etc. conventionally, it considers as slab by the continuous casting process, or ingot making and a cogging method. Subsequently, after considering as a predetermined configuration with hot rolling, graphitizing is performed and the graphite phase of the specified quantity is deposited all over a metal texture. Thus, after that, the manufactured invention steel is fabricated to a predetermined part shape, and let it be a machine part. In addition, nitriding treatment may be performed and it may consider as a product.

[0043] It is desirable to make whenever [in the above-mentioned hot rolling / stoving temperature] into 1000 degrees C or more. Since hot-working nature deteriorates here when a machinability element is included, it is desirable to make whenever [before the above-mentioned hot rolling / stoving temperature] into 1000 degrees C or more, and to roll out at the temperature more than 850 **.

[0044] Thus, graphitization is attained only by annealing processing, without performing quenching processing, after hot-rolling. What is necessary is just to hold the annealing conditions for obtaining 10% or more of graphite phase required for reservation of the machinability by the self-lubrication action mentioned above in the temperature requirement of 600 **-Ac1 for 5 to 30 hours. In addition, when the element which checks graphitization of Te, P, Bi, Pb, etc. as a free-cutting element is contained independently, it is [above-mentioned] within the limits, and it is desirable to lengthen the holding time.

[0045]

[Example]

Hot rolling after ingoting with a converter the steel materials which become the component presentation shown in example 1 table 1 and Table 2 and using them as the bloom by continuous casting after vacuum-degassing processing It considered as the billet of 150mm angle. Subsequently, after using these billets as the steel bar of 52mmphi with steel bar rolling, graphitization processing of 700 ** and 10h-> air cooling was performed. It investigated about the hardness, the rate of graphitization, and graphite

particle size after graphitizing annealing of the steel materials obtained in this way. In addition, the ratio with the amount of graphites when all of the measured amount of graphites and added C graphitize defined the rate of graphitization. Moreover, the machinability trial by high speed tool steel was performed, and it investigated also about the tool life. The machinability trial used high speed tool steel SKH4, and the conditions of periphery lathe turning performed it here. the slitting depth and the feed per revolution at the time of cutting -- respectively -- 2.0mm, 0.25mm/rev., and cutting speed -- 70 m/min it is -- time amount until cutting becomes impossible was defined as the tool life. The obtained test result is shown in Table 3.

[0046]

[Table 1]

No.	化学組成 (mass%)													備考
	C	Si	Mn	REM	N	O	Cr	Mo	Ni	Cu	V	Nb	Pb	
1	0.15	1.40	0.82	0.0098	0.0056	0.0013	—	—	—	—	—	—	—	第1発明
2	0.33	1.07	0.72	0.0050	0.0077	0.0016	—	—	—	—	—	—	—	〃
3	0.73	1.49	1.09	0.0149	0.0055	0.0016	—	—	—	—	—	—	—	〃
4	1.04	1.18	0.38	0.0145	0.0058	0.0015	—	—	—	—	—	—	—	〃
5	1.33	1.18	0.20	0.0057	0.0079	0.0013	—	—	—	—	—	—	—	〃
6	0.53	0.91	1.11	0.0213	0.0068	0.0016	—	—	—	—	—	—	—	〃
7	0.54	1.06	0.30	0.0120	0.0051	0.0013	—	—	—	—	—	—	—	〃
8	0.53	1.42	0.30	0.0139	0.0080	0.0013	0.34	—	—	—	—	—	—	第3発明
9	0.52	1.04	0.28	0.0132	0.0059	0.0011	—	0.27	—	—	—	—	—	〃
10	0.53	1.40	0.33	0.0109	0.0078	0.0013	—	—	—	—	0.21	—	—	第5発明
11	0.52	1.04	0.29	0.0124	0.0072	0.0013	—	—	—	—	—	0.033	—	〃
12	0.50	0.83	0.28	0.0086	0.0043	0.0015	—	—	0.39	—	—	—	—	〃
13	0.51	1.36	0.32	0.0108	0.0048	0.0016	—	—	—	0.36	—	—	—	〃
14	0.54	1.27	0.31	0.0148	0.0042	0.0013	0.30	—	—	—	0.31	—	—	第7発明
15	0.52	1.09	0.32	0.0087	0.0042	0.0013	—	0.27	0.58	—	—	—	—	〃
16	0.53	1.38	0.30	0.0057	0.0077	0.0011	—	—	—	0.34	—	0.015	—	第5発明
17	0.54	1.19	0.32	0.0050	0.0065	0.0017	0.24	—	0.84	—	—	0.011	—	第7発明
18	0.53	1.49	0.29	0.0058	0.0063	0.0010	—	0.41	0.63	0.38	—	—	—	〃
19	0.51	1.09	0.30	0.0088	0.0049	0.0014	—	—	1.29	—	0.22	0.023	—	〃
20	0.51	1.21	0.33	0.0084	0.0045	0.0013	0.34	0.24	—	1.19	0.24	—	—	〃
21	0.55	1.02	0.32	0.0090	0.0074	0.0013	0.36	—	1.05	—	0.15	0.029	—	〃
22	0.50	1.09	0.32	0.0087	0.0041	0.0016	0.35	0.27	0.50	0.49	0.44	0.026	—	〃

[0047]

[Table 2]

[0048]
[Table 3]

No.	化学組成 (mass%)													備考
	C	Si	Mn	REM	N	O	Cr	Mo	Ni	Cu	V	Nb	Pb	
23	0.53	1.07	2.53	0.0095	0.0054	0.0015	—	—	—	—	—	—	—	比較鋼
24	0.53	0.15	0.31	0.0079	0.0051	0.0017	—	—	—	—	—	—	—	〃
25	0.53	1.13	0.37	0.0087	0.0213	0.0015	—	—	—	—	—	—	—	〃
26	0.50	1.43	0.31	—	0.0076	0.0016	—	—	—	—	—	—	—	〃
27	0.55	1.00	0.31	0.0071	0.0052	0.0042	—	—	—	—	—	—	—	〃
28	0.53	1.41	0.88	—	0.0073	0.0015	—	—	—	—	—	—	0.34	従来例
29	0.13	1.03	0.95	—	0.0080	0.0017	—	—	—	—	—	—	0.28	〃

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	工具寿命 (min)	QT後の硬さ (Hv)	備　考
1	100	2.1	74	255	第1発明
2	100	3.9	62	318	〃
3	100	5.8	54	392	〃
4	100	9.9	61	394	〃
5	100	13.3	57	388	〃
6	100	5.6	58	371	〃
7	100	5.4	64	365	〃
8	100	7.2	57	374	第3発明
9	100	6.6	59	378	〃
10	100	4.1	67	376	第5発明
11	100	5.3	65	380	〃
12	100	6.0	64	370	〃
13	100	3.9	68	379	〃
14	97	7.4	56	379	第7発明
15	100	6.4	58	383	〃
16	99	4.3	68	377	第5発明
17	100	7.4	55	394	第7発明
18	98	5.6	60	400	〃
19	100	4.6	65	392	〃
20	100	8.8	49	396	〃
21	100	9.0	49	397	〃
22	97	9.5	45	387	〃
23	4	3.1	4	360	比較例
24	19	8.2	8	362	〃
25	43	12.3	11	366	〃
26	16	10.4	6	360	〃
27	33	11.5	7	361	〃
28	—	—	18	325	従来例
29	—	—	35	224	〃

[0049] Front Naka and No.1-22 are this invention steel. Again No.23-27 are the comparison steel with which either of the components deviated from the proper range of this invention. In addition No.28 are Pb free cutting steel which added Pb to JIS S53C, and No.29. SAE Specification It is 12L14 about steel. each [this invention steel] so that clearly from Table 3 -- 700 degree C and graphitization processing of 10h maintenance -- the inside C of steel -- almost -- 100% is graphitized. Moreover, the graphite particle size

after processing of this invention steel is also detailed, and it turns out that many graphite grains exist. Therefore, it excels in machinability and is steel No.29. SAE Specification The tool life equivalent to 12L14 about steel is acquired. On the other hand, Mn, Si, and N, P, O and REM In order that graphitization may take long duration to steel No.23 -27 which deviated from the proper range of this invention, by 10h processing, graphitization does not fully advance, therefore machinability is also inferior in them compared with this invention steel.

[0050] The steel materials which become the component presentation shown in example 2 table 4 and Table 5 were processed like the example 1, and were used as the steel bar of 52mmphi. The result investigated about the hardness, the rate of graphitization, the graphite particle size, and the tool life of the steel materials obtained in this way is shown in Table 6.

[0051]

[Table 4]

組成 (mass%)											備考
	B	Cr	Mo	Ni	Cu	V	Nb	Al	Ti	Pb	
2	0.0034	—	—	—	—	—	—	—	—	—	第2発明
6	0.0055	—	—	—	—	—	—	—	—	—	〃
4	0.0035	—	—	—	—	—	—	—	—	—	〃
6	0.0032	—	—	—	—	—	—	—	—	—	〃
1	0.0015	—	—	—	—	—	—	—	—	—	〃
3	0.0050	—	—	—	—	—	—	—	—	—	〃
6	0.0054	—	—	—	—	—	—	—	—	—	〃
0	0.0019	—	—	—	—	—	—	0.034	—	—	第6発明
5	0.0025	—	—	—	—	—	—	—	0.010	—	〃
6	0.0017	—	—	0.53	—	—	—	—	—	—	〃
3	0.0058	—	—	—	0.32	—	—	—	—	—	〃
4	0.0030	0.26	—	—	—	—	—	—	—	—	第4発明

[0052]
[Table 5]

No.	化学組成 (mass%)																備考
	C	Si	Mn	REM	N	O	B	Cr	Mo	Ni	Cu	V	Nb	Al	Ti	Pb	
20	0.51	1.30	0.31	0.0075	0.0053	0.0014	0.0046	—	0.45	1.10	—	0.30	—	—	—	—	第8発明
21	0.54	0.99	0.29	0.0118	0.0079	0.0014	0.0049	0.47	—	—	1.13	—	—	—	0.032	—	〃
22	0.52	0.83	0.30	0.0107	0.0044	0.0018	0.0058	—	0.14	—	1.03	—	0.017	0.029	—	—	〃
23	0.55	1.25	0.32	0.0146	0.0075	0.0017	0.0029	0.39	—	0.68	—	—	0.042	—	0.030	—	〃
24	0.51	1.24	0.31	0.0116	0.0049	0.0014	0.0059	0.13	—	—	—	—	0.013	0.025	0.025	—	〃
25	0.52	0.82	0.29	0.0074	0.0062	0.0010	0.0057	—	0.50	1.15	1.09	0.46	—	—	—	—	〃
26	0.51	0.81	0.29	0.0125	0.0045	0.0011	0.0019	—	0.18	—	0.70	0.43	0.024	0.057	—	—	〃
27	0.51	0.81	0.30	0.0089	0.0047	0.0014	0.0022	0.45	0.38	0.52	—	0.46	—	—	0.038	—	〃
28	0.52	0.90	0.29	0.0073	0.0054	0.0011	0.0021	0.16	—	1.04	1.21	—	0.041	0.060	0.020	—	〃
29	0.51	0.93	0.33	0.0114	0.0041	0.0013	0.0058	0.20	0.21	—	1.29	0.29	0.036	0.064	—	—	〃
30	0.52	0.87	0.29	0.0129	0.0048	0.0017	0.0051	0.18	0.41	1.18	0.85	0.40	0.036	0.039	0.014	—	〃
31	0.51	1.07	2.48	0.0115	0.0044	0.0013	0.0037	—	—	—	—	—	—	—	—	—	比較例
32	0.52	0.10	0.30	0.0126	0.0080	0.0013	0.0034	—	—	—	—	—	—	—	—	—	〃
33	0.51	1.50	0.30	0.0107	0.0244	0.0012	0.0021	—	—	—	—	—	—	—	—	—	〃
34	0.54	0.97	0.28	—	0.0041	0.0016	0.0016	—	—	—	—	—	—	—	—	—	〃
35	0.53	1.07	0.29	0.0141	0.0048	0.0043	0.0017	—	—	—	—	—	—	—	—	—	〃
36	0.53	1.41	0.88	—	0.0073	0.0015	—	—	—	—	—	—	—	—	—	0.34	従来例
37	0.13	1.03	0.95	—	0.0080	0.0017	—	—	—	—	—	—	—	—	—	0.28	〃

[0053]
[Table 6]

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	工具寿命 (min)	QT後の硬さ (Hv)	備考
1	100	1.9	59	239	第2発明
2	100	2.3	69	326	〃
3	100	8.5	60	388	〃
4	100	10.5	82	390	〃
5	100	13.1	92	394	〃
6	100	4.2	60	370	〃
7	100	2.8	82	363	〃
8	100	3.4	84	378	第6発明
9	100	3.5	83	377	〃
10	100	3.2	81	378	〃
11	100	3.7	82	370	〃
12	100	8.3	73	381	第4発明
13	100	6.0	72	376	〃
14	101	4.5	80	391	第6発明
15	102	3.5	83	393	〃
16	100	7.2	74	392	第8発明
17	99	5.2	79	389	第6発明
18	99	7.0	72	385	第8発明
19	100	4.4	80	392	第6発明
20	100	5.5	73	398	第8発明
21	100	8.5	70	397	〃
22	100	5.0	76	395	〃
23	100	7.1	70	396	〃
24	100	3.9	79	394	〃
25	100	7.0	70	393	〃
26	100	5.2	74	394	〃
27	100	11.4	58	395	〃
28	100	4.7	75	391	〃
29	100	5.9	70	397	〃
30	97	7.0	65	393	〃
31	6	3.1	5	370	比較例
32	21	8.2	8	368	〃
33	44	12.3	13	372	〃
34	82	6.4	46	374	〃
35	33	11.5	9	375	〃
36	—	—	18	325	従来例
37	—	—	35	224	〃

[0054] Front Naka and No.1-30 are this invention steel. Again No.31-35 are the comparison steel with which either of the components deviated from the proper range of this invention. In addition Pb free cutting steel with which No.36 added Pb to JIS S53C, and No.37 are SAE. Specification It is 12L14 about steel. clear from Table 6 -- as -- No.1-30 -- each -- graphitization -- quick -- going on -- the inside C of steel -- almost -- 100% is graphitized. Moreover, the graphite particle size after processing is also detailed, and it turns out that many graphite grains exist. For this reason, steel No.37 SAE Specification The tool life equivalent to 12L14 about steel is acquired. On the other hand, graphitization does not fully advance, therefore machinability is also inferior in steel No.31 -35 to which various components have deviated from the proper range of this invention compared with this invention steel.

[0055] The steel materials which become the component presentation shown in example 3 table 7 were processed like the example 1, and were used as the steel bar of 52mmphi. The result investigated about the hardness, the rate of graphitization, the graphite particle size, and the tool life of the steel materials obtained in this way is shown in Table 8.

[0056]

[Table 7]

[0057]
[Table 8]

No.	化学組成 (mass%)																			備考
	C	Si	Mn	REM	N	O	Cr	Mo	Ni	Cu	V	Nb	Pb	Te	Ca	Bi	Se	P	S	
1	0.59	1.95	0.36	0.0452	0.0148	0.0010	–	–	–	–	–	–	0.27	0.13	–	–	–	–	–	第9発明
2	0.67	1.77	0.33	0.0075	0.0143	0.0014	–	–	–	–	–	–	–	0.42	–	0.18	0.012	–	–	〃
3	1.31	1.38	0.80	0.0222	0.0076	0.0022	–	–	–	–	–	–	0.16	0.18	–	0.28	0.041	–	–	〃
4	0.69	1.50	0.59	0.0361	0.0051	0.0016	–	–	–	–	–	–	–	0.05	0.017	–	–	–	–	〃
5	0.92	1.78	0.60	0.0036	0.0070	0.0019	–	–	–	–	–	–	0.08	–	0.021	0.09	–	0.067	–	〃
6	0.98	1.78	1.24	0.0225	0.0149	0.0021	–	–	–	–	–	–	–	–	0.017	0.18	0.087	–	–	〃
7	0.16	1.05	0.30	0.0234	0.0099	0.0011	–	–	–	–	–	–	0.24	–	0.018	0.29	0.025	–	–	〃
8	0.42	1.49	0.58	0.0238	0.0021	0.0010	–	–	–	–	–	–	0.09	0.32	0.125	–	0.084	–	0.146	〃
9	0.78	1.91	0.95	0.0064	0.0094	0.0015	–	–	–	–	0.34	–	0.15	0.22	0.017	0.24	0.042	–	–	第13発明
10	0.69	1.49	0.58	0.0172	0.0044	0.0015	0.35	–	–	–	–	–	–	0.05	0.017	–	–	0.067	–	第11発明
11	0.90	1.78	0.59	0.0098	0.0064	0.0017	–	0.35	–	–	–	–	0.08	–	0.021	0.09	–	0.078	0.048	〃
12	1.08	1.76	0.35	0.0054	0.0136	0.0007	–	–	2.73	0.57	0.23	–	–	0.27	0.006	0.25	–	–	0.049	第13発明
13	0.47	1.25	0.33	0.0280	0.0066	0.0010	–	–	–	0.98	–	–	0.24	0.24	0.015	0.15	–	–	–	〃
14	1.01	1.79	1.24	0.0282	0.0143	0.0020	–	0.41	2.55	–	–	–	–	–	0.017	0.18	0.087	–	0.235	第15発明
15	1.22	0.69	1.79	0.0049	0.0123	0.0018	0.37	–	2.05	0.85	0.11	–	–	0.31	0.017	–	0.047	–	0.138	〃
16	0.14	1.04	0.32	0.0234	0.0100	0.0011	0.25	0.35	–	–	–	–	0.24	–	0.018	0.29	0.025	–	0.245	第11発明
17	0.41	1.49	0.57	0.0088	0.0024	0.0010	0.57	0.45	–	0.54	–	–	0.09	0.32	0.123	–	0.084	–	0.146	第15発明
18	0.77	1.91	0.96	0.0096	0.0095	0.0013	0.23	0.23	1.58	–	–	–	0.15	0.22	0.017	0.24	0.042	–	0.055	〃
19	0.16	1.03	0.31	0.0070	0.0100	0.0009	–	–	1.08	–	–	0.035	0.24	–	0.018	0.29	0.025	–	0.245	第13発明
20	0.41	1.46	0.58	0.0150	0.0019	0.0008	–	0.41	2.55	–	0.25	–	0.09	0.32	0.125	–	0.084	–	0.146	第15発明
21	0.77	1.87	0.97	0.0089	0.0091	0.0013	0.37	–	2.05	0.85	0.15	0.013	0.15	0.22	0.017	0.24	0.042	–	–	〃
22	0.66	1.78	0.32	0.0097	0.0145	0.0016	0.23	0.23	1.58	–	0.25	–	–	0.42	–	0.18	0.012	–	0.085	〃
23	0.59	2.15	0.36	–	0.0145	0.0009	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
24	1.44	1.89	1.60	–	0.0085	0.0019	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
25	0.47	1.26	0.33	–	0.0063	0.0009	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
26	0.05	0.04	0.93	–	0.0117	0.0016	–	–	–	–	–	–	0.34	–	–	–	–	–	–	従来例
27	0.43	0.25	0.77	–	0.0089	0.0018	–	–	–	–	–	–	0.28	–	–	–	–	–	–	〃

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	工具寿命 (min)	QT後の硬さ (Hv)	備　考
1	100	3.7	90.1	378	第9発明
2	96	11.8	81.5	391	〃
3	100	30.2	92.8	390	〃
4	100	11.2	84.8	387	〃
5	97	20.2	74.4	386	〃
6	100	18.2	97.8	381	〃
7	100	0.9	94.5	260	〃
8	100	1.8	93.1	344	〃
9	100	9.0	108.0	424	第13発明
10	100	11.2	79.7	422	第11発明
11	99	5.6	103.7	420	〃
12	99	17.2	155.0	416	第13発明
13	100	3.5	101.8	390	〃
14	100	10.4	110.9	423	第15発明
15	100	30.8	91.5	417	〃
16	99	1.1	85.7	280	第11発明
17	100	1.8	99.8	371	第15発明
18	100	1.6	122.7	417	〃
19	100	1.5	112.9	293	第13発明
20	100	2.2	109.8	377	第15発明
21	100	6.4	120.9	419	〃
22	100	5.8	92.8	415	〃
23	96	10.2	53.0	402	〃
24	93	38.2	35.4	425	〃
25	68	11.7	35.2	383	〃
26	—	—	40.0	211	従来例
27	—	—	22.0	379	〃

[0058] Front Naka and No.1-22 are this invention steel. Moreover, No.23 -25 are the comparison steel with which either of the components deviated from the proper range of this invention. In addition, No.26 SAE which is the compound free cutting steel of Pb-S-P Specification 12L14 about steel and No.27 It is Pb free cutting steel which added Pb to JIS S45C. Each steel cannot but be below 53.0 min comparison steel and conventionally to the tool life of this invention steel showing the very good life more than 74.4 min. that is, the machinability which was markedly alike and was superior to the conventional steel with this invention becomes possible.

[0059] The steel materials which become the component presentation shown in example

4 table 9 and Table 10 were processed like the example 1, and were used as the steel bar of 52mmphi. The result investigated about the hardness, the rate of graphitization, the graphite particle size, and the tool life of the steel materials obtained in this way is shown in Table 11.

[0060]

[Table 9]

[0061]
[Table 10]

No.	化学組成 (mass%)																					備考
	C	Si	Mn	REM	N	O	B	Cr	Mo	Ni	Cu	V	Nb	Al	Ti	Pb	Te	Ca	Bi	Se	P	S	
1	0.58	1.95	0.37	0.0454	0.0146	0.0008	0.0052	–	–	–	–	–	–	–	–	0.27	0.13	–	–	–	–	–	第10発明
2	0.28	1.65	1.49	0.0040	0.0138	0.0022	0.0132	–	–	–	–	–	–	–	–	–	0.38	–	–	0.087	0.033	0.207	〃
3	0.68	1.78	0.33	0.0073	0.0143	0.0015	0.0138	–	–	–	–	–	–	–	–	–	0.42	–	0.18	0.012	–	0.085	〃
4	1.33	1.38	0.79	0.0218	0.0077	0.0021	0.0008	–	–	–	–	–	–	–	–	0.16	0.18	–	0.28	0.041	–	–	〃
5	0.67	1.49	0.58	0.0165	0.0048	0.0015	0.0149	–	–	–	–	–	–	–	–	–	0.05	0.017	–	–	–	–	〃
6	0.91	1.79	0.59	0.0058	0.0068	0.0018	0.0146	–	–	–	–	–	–	–	–	0.08	–	0.021	0.09	–	0.067	0.048	〃
7	0.48	1.25	0.32	0.0014	0.0065	0.0009	0.0015	–	–	–	–	0.15	–	0.069	–	0.24	0.24	0.015	0.15	–	–	–	第14発明
8	0.99	1.78	1.23	0.0227	0.0146	0.0022	0.0138	–	–	–	–	–	–	0.021	–	–	–	0.017	0.18	0.087	–	–	〃
9	0.15	1.03	0.32	0.0130	0.0103	0.0011	0.0021	–	–	–	–	–	–	–	–	0.24	–	0.018	0.29	0.025	–	–	第10発明
10	0.42	1.47	0.59	0.0242	0.0022	0.0009	0.0009	–	–	–	–	–	–	0.042	–	0.09	0.32	0.125	–	0.084	–	0.146	第14発明
11	0.78	1.89	0.95	0.0064	0.0095	0.0013	0.0025	–	–	–	–	0.34	–	–	–	0.15	0.22	0.017	0.24	0.042	–	–	〃
12	0.67	1.49	0.58	0.0169	0.0048	0.0015	0.0149	0.35	–	–	–	–	–	–	–	–	0.05	0.017	–	–	–	–	第12発明
13	0.91	1.79	0.59	0.0099	0.0068	0.0018	0.0146	–	–	–	–	–	–	–	0.017	0.08	–	0.021	0.09	–	0.067	0.048	第14発明
14	1.07	1.75	0.35	0.0054	0.0139	0.0006	0.0016	–	–	2.73	0.57	0.23	–	0.022	–	–	0.27	0.006	0.25	–	0.078	0.049	〃
15	0.48	1.25	0.32	0.0279	0.0065	0.0009	0.0015	–	–	–	0.98	–	–	–	–	0.24	0.24	0.017	0.15	–	–	–	〃
16	0.99	1.78	1.23	0.0285	0.0146	0.0022	0.0138	–	–	2.55	–	–	–	–	–	–	–	0.017	0.18	0.087	–	0.235	〃
17	1.23	0.68	1.78	0.0054	0.0123	0.0018	0.0028	0.37	–	2.05	0.85	0.11	–	0.015	–	–	0.31	0.017	–	0.047	–	0.138	第16発明
18	0.15	1.03	0.32	0.0233	0.0103	0.0011	0.0021	0.25	–	–	–	–	–	–	0.018	0.24	–	0.018	0.29	0.025	–	0.245	〃
19	0.42	1.47	0.59	0.0090	0.0022	0.0009	0.0009	0.57	0.45	–	0.54	–	–	–	–	0.09	0.32	0.125	–	0.084	–	0.146	〃
20	0.78	1.89	0.95	0.0096	0.0095	0.0013	0.0025	0.23	0.23	1.58	–	–	–	–	–	0.15	0.22	0.017	0.24	0.042	–	–	〃

[0062]
[Table 11]

No.	化学組成 (mass%)																					備考
	C	Si	Mn	REM	N	O	B	Cr	Mo	Ni	Cu	V	Nb	Al	Ti	Pb	Te	Ca	Bi	Se	P	S	
21	0.15	1.03	0.32	0.0070	0.0103	0.0011	0.0021	–	–	1.08	–	–	0.035	–	–	0.24	–	0.018	0.29	0.025	–	0.245	第14発明
22	0.42	1.47	0.59	0.0150	0.0022	0.0009	0.0009	–	0.41	2.55	–	0.25	–	–	–	0.09	0.32	0.125	–	0.084	–	0.146	第16発明
23	0.78	1.89	0.95	0.0090	0.0095	0.0013	0.0013	0.37	–	2.05	0.85	0.15	0.013	–	0.045	0.15	0.22	0.017	0.24	0.042	–	–	〃
24	0.68	1.78	0.33	0.0070	0.0143	0.0015	0.0015	0.23	0.23	1.58	–	0.25	–	–	0.044	–	0.42	–	0.18	0.012	–	0.085	〃
25	1.06	1.72	0.59	–	0.0087	0.0019	0.0019	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	比較例
26	0.58	2.15	0.37	–	0.0146	0.0008	0.0008	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
27	1.45	1.88	1.58	–	0.0087	0.0018	0.0018	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
28	0.48	1.25	0.32	–	0.0065	0.0009	0.0009	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	〃
29	0.07	0.02	0.93	–	0.0121	0.0015	–	–	–	–	–	–	–	–	–	0.34	–	–	–	–	–	–	従来例
30	0.45	0.24	0.76	–	0.0085	0.0017	–	–	–	–	–	–	–	–	–	0.28	–	–	–	–	–	–	〃

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	工具寿命 (min)	QT後の硬さ (Hv)	備考
1	100	0.6	88.4	370	第10発明
2	100	0.3	67.7	312	〃
3	100	4.2	99.9	385	〃
4	89	20.8	73.0	392	〃
5	100	3.8	80.1	392	〃
6	100	12.5	92.3	393	〃
7	99	10.4	66.5	386	第14発明
8	100	11.2	108.7	387	〃
9	92	6.6	90.8	255	第10発明
10	95	6.6	90.7	342	第14発明
11	99	7.8	99.4	422	〃
12	100	3.8	78.3	417	第12発明
13	100	2.1	112.1	416	第14発明
14	100	16.9	96.3	422	〃
15	90	2.7	75.4	389	〃
16	100	3.5	112.8	419	〃
17	100	29.3	73.6	419	第16発明
18	88	5.5	84.8	285	〃
19	92	6.2	91.9	377	〃
20	100	0.4	111.3	417	〃
21	96	0.6	102.2	285	第14発明
22	100	2.0	112.0	372	第16発明
23	100	6.2	107.6	417	〃
24	100	5.6	110.5	418	〃
25	84	24.4	55.4	424	比較例
26	100	8.2	60.5	399	〃
27	84	36.4	59.8	425	〃
28	60	11.7	36.1	390	〃
29	—	—	40.0	211	従来例
30	—	—	22.0	379	従来例

[0063] Front Naka and No.1-24 are this invention steel. Moreover, No.25 -28 are the comparison steel with which either of the components deviated from the proper range of this invention. In addition, No.29 SAE which is the compound free cutting steel of Pb-S-P Specification 12L14 about steel and No.30 It is Pb free cutting steel which added Pb to JIS S45C. Each steel cannot but be below 60.5 min comparison steel and conventionally to the tool life of this invention steel showing the very good life more than 66.5 min. that is, the machinability which was markedly alike and was superior to the conventional steel with this invention becomes possible.

[0064]

[Effect of the Invention] According to this invention, it is **(ing)-to manufacture of machine part as which steel materials which have machinability superior to conventional Pb free cutting steel can be easily obtained industrially, and high machinability is required size in this way.

[Translation done.]